Department of Biosystems
and Agricultural Engineering
MICHIGAN STATE UNIVERSITY

**BE 487 - Spring 2022**
**Biosystems Design Projects**

# BE 487 – USGS: Sterilization of Male Sea Lampreys with Bisazir

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## Background

The United States Geological Survey (USGS) reached out to the Michigan State University Biosystems Engineering department in search of an update to the current method or a new design to sterilize male sea lampreys.

Why target male sea lampreys?

- Sea lampreys are an invasive species in the Great Lakes
- One male spawn with multiple female
- Lampreys die soon after mating, meaning one sterilized male results in death of itself, numerous females, and several batches of eggs (1).

The current sterilization method utilized at the USGS site in Hammond Bay, MI strives to sterilize 5,000 male sea lamprey per season through injection of the compound Bisazir, a highly mutagenic compound, to sterilize lamprey.

Problem Statement:
Design an effective and efficient sea lamprey sterilization method that minimizes hazards to employees, increases overall volume of lamprey sterilized, and minimizes lamprey mortality during processing.


Figure 1: The invasive sea lamprey

## Objectives

The project objectives are as follows:

- Decrease safety risk for workers
- Reduce lamprey mortality to below 3.1%
- Sterilize 10,000 lampreys/season
- Keep estimated design cost below $1,000,000

## Constraints

The project constraints are as follows:

- Follow OSHA standard 1910.1450 for handling of mutagenic compounds (2)
- Prevent discharge of Bisazir into the watershed in accordance with the Clean Water Act (3)
- Ensure lamprey are healthy and active after processing
- Limit design costs to below $2,000,000

## Design Alternatives

The team developed four viable design alternatives to solve the problem statement. The alternatives included:

1. Modification to the current design
   - Injection of Bisazir
   - Updates to the current system would include swapping out specific parts to improve reliability
   - Update to include an automatic feeding system to decrease human interaction
2. Immersion in an aqueous solution of Bisazir
   - Immersion transfers the compound into the lamprey's system naturally via ingestion
   - Eliminates the need for direct injection and potential misses in injection site resulting in the death of the animal
   - A series of trials was performed at the Hammond Bay Facility in 1977 and 1978 of varying treatment lengths and dosages of Bisazir. The results indicated that at a 2hour treatment time and a 100 mg/L concentration sterilization was 99.7% effective
   - Trials also indicated that no lamprey mortality was reported during the immersion process (4)
3. Immersion in a solution of gossypol
   - Like alternative number 2, gossypol would be utilized via immersion
   - Gossypol is not mutagenetic, therefore significantly lowering the risk to workers.
   - Not tested for sea lamprey sterilization
4. Thermal sterilization
   - Ecofriendly alternative utilizing heat treatment
   - Best rating of the alternatives regarding human safety.
   - Not tested for sea lamprey sterilization

## Selected Design

The design selected to move forward with was the immersion of the lamprey in an aqueous solution of Bisazir. This design was selected for its simplicity, low cost, sterilization effectiveness, and low lamprey mortality rate. The design steps include:

1. Placing batches of 300 lampreys into 8 aerated freshwater tanks (figure 3) using the current facilities crane. Suggested floorplan can be seen in figure 2
2. Mixing a large batch of diluted Bisazir solution until a final concentration of 100 mg/L is achieved
3. Draining each tank of freshwater and pumping the Bisazir solution in to replace it
4. Allowing 2 hours of treatment time while the lampreys sit in the Bisazir solution
5. Drain each tank of the Bisazir solution that runs out to the current carbon filtration system to ensure a clean effluent
6. Tanks are then refilled with freshwater with a constant inflow and an overflow pipe to ensure a tank cycle rate of about 1 hour
7. Allowing for a 48-hour recovery period in the freshwater baths
8. Draining the freshwater from each tank and removing nets (figure 4) full of lamprey to be released back into the wild

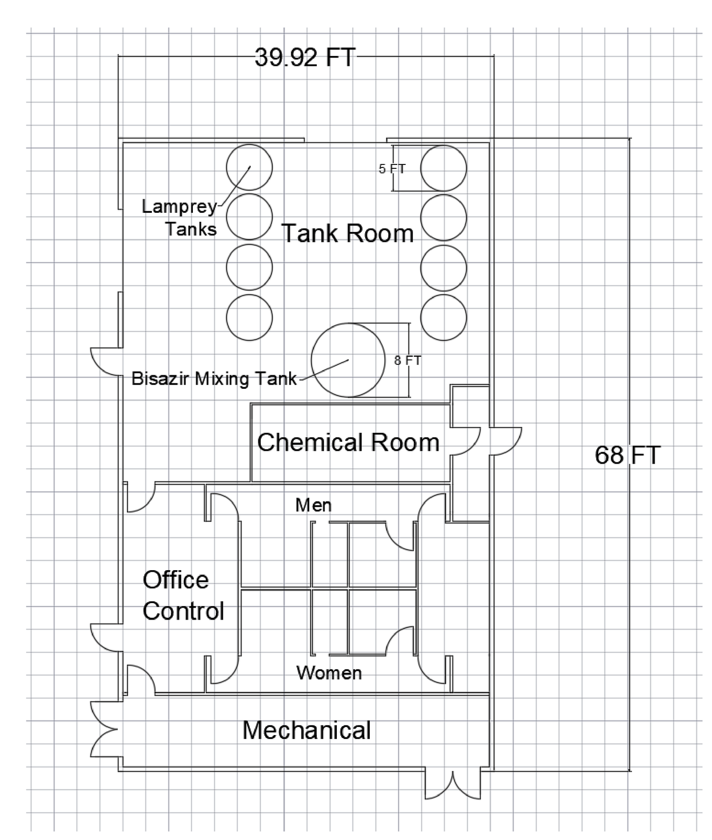

Figure 2: Floor plan of the Hammond Bay, MI USGS facility

## Design Parameters

Each alternative was evaluated and compared using a decision matrix, table 1, based on the following parameters:

- Human safety
- Lamprey mortality
- Effectiveness of sterilization
- Commercial readiness
- Cost

Table 1: Design alternatives decision matrix

| Criteria | Weight (1-10) | Modify current injection machine | Immersion in Bisazir | Gossypol treatment | Thermal sterilization |
|---|---|---|---|---|---|
| Human safety | 10 | 3 | 6 | 7 | 10 |
| Lamprey mortality | 7 | 7 | 10 | 2 | 7 |
| Effectiveness of sterilization | 7 | 10 | 9 | 6 | 8 |
| Commercial readiness | 5 | 10 | 9 | 1 | 1 |
| Cost | 3 | 5 | 9 | 6 | 6 |
| Weighted result | | 214 | 265 | 149 | 228 |

As can be seen in table 1, the immersion in Bisazir was rated highly for most of the design parameters. In prior tests of the immersion technique, there was no lamprey mortality. Testing also yielded a 99.7% effectiveness for sterilization. In addition, this solution's simplicity yields a low cost and high commercial readiness. This solution ranked lower for human safety initially due to the use of Bisazir, a mutagenic compound, but with the operation and safety manual provided the threat has been minimized.

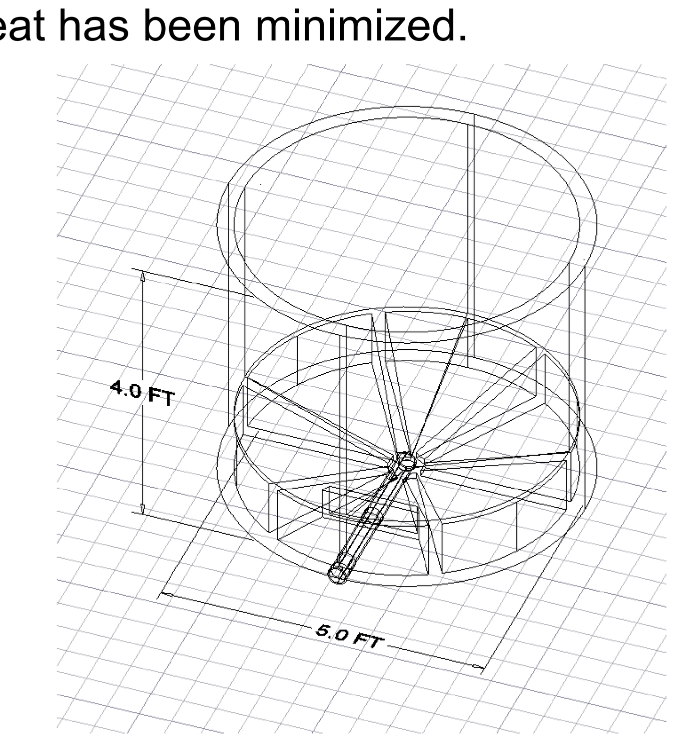

Figure 3: Holding/treatment tank design

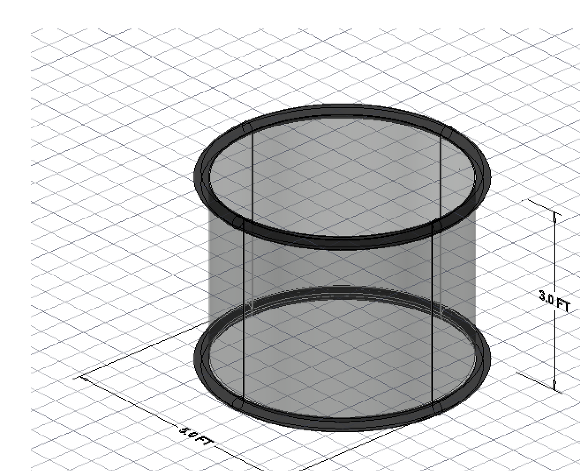
Figure 4: Netting for the holding/treatment tanks

## Economics

The budget for this project was originally set at a maximum of $2,000,000 due to an upcoming grant renewal. The team goal was to be able to match or end up below the manufacture price of the current bisazir injection machine that previously was set at a cost of $500,000. Due to the simplicity of switching to an immersion technique the cost of equipment and construction dropped tremendously. As can be seen in table 2 below the cost came in well under budget at about $193,000.

Table 2: Project budget

| Material List | Description | # | Cost (per unit) | Total Cost |
|---|---|---|---|---|
| Mixing tank | 3000 gallons, sealed tank, with mixer inside | 1 | $ 48,222 | $ 48,222 |
| Pump | 1/2 HP centrifugal pump | 1 | $ 1,094 | $ 1,094 |
| Holding/ Treatment Tanks | 60" DIAM X 51" H cylindrical tank with a bolt on lid and a cone bottom. | 8 | $ 7,418 | $ 59,344 |
| Acid sprayer | ACID Hand-Held Compression Sprayer | 1 | $ 100 | $ 100 |
| Net | 12 x 20 Ft Heavy Duty Backyard Fishpond Netting, Black | 8 | $ 39 | $ 312 |
| Stainless tubing | Polished Stainless-Steel Tubing - Price Per 20-ft Length | 16 | $ 200 | $ 3,200 |
| Air Pump | 600GPH Commercial Air Pump | 8 | $ 39 | $ 312 |
| Aerator tubing | Standard Airline Tubing – Clear and Flexible, 8 Feet | 8 | $ 2 | $ 16 |
| Diffuser stones | Large Air Stone Cylinder, Aerator Bubble Diffuser | 8 | $ 12 | $ 96 |
| Operating cost (per season) | Bisazir, Menthol, Acetate Syringe filters, Flasks | 1 | $ 68,685 | $ 68,685 |
| Misc. Hardware | Chemical hose, tri-clamp fittings and adapters, tank hooks, 2.5-gallon HDPE container | 1 | $ 11,873 | $ 11,873 |
| Grand Total | | | | $ 193,254 |

## Select References

1. Docker, M. F. (2015). Lampreys: Biology, conservation, and control (Vol. 1). Springer.
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4. Hanson, L. H. (1981, October). Sterilization of sea lampreys (Petromyzon marinus) by immersion in an aqueous solution of Bisazir. Canadian Journal of Fisheries and Aquatic Sciences, 38(10), 1285-1289. https://doi.org/10.1139/f81-172.